Amendments to the Specification

Please amend the title as follows:

METHOD OF DETECTING POSITION OF ROTATION AXIS OF SUCTION NOZZLE~~,~~ ~~AND ELECTRIC COMPONENT MOUNTING SYSTEM~~

Please replace paragraph **[0011]** with the following rewritten paragraph:

[0011] (3) A method according to the first feature (1), wherein the step of detecting the position comprises steps of:

preparing a calibration member having, substantially on the position-detecting plane, a support surface and at least one first positioning reference,

placing, on the support surface, a calibration gauge having at least one second positioning reference,

taking, with an image-taking device, a first image of the first positioning ~~image~~ reference and the second positioning ~~image,~~ reference,

holding, with the suction nozzle, the calibration gauge to move the gauge off the support surface,

rotating the suction nozzle holding the calibration gauge, about the rotation axis of the nozzle, to rotate the gauge by a predetermined angle,

placing, with the suction nozzle, the calibration gauge rotated by the predetermined angle, on the support surface,

taking, with the image-taking device, a second image of the first positioning ~~image~~ reference and the second positioning ~~image,~~ reference, and

processing the first image and the second image, to determine a relative position between a reference point of the calibration member and the position of the rotation axis of the suction nozzle.

Please replace paragraph **[0012]** with the following rewritten paragraph:

[0012] The calibration member may have the support surface literally level with the position-detecting plane, and has at least one first positioning reference on at least one reference surface more or less vertically distant from the position-detecting plane, e.g., by a distance equal to a thickness of the calibration gauge. The step of detecting the position may comprise repeating, at least one more time, the step of holding the calibration gauge, the step of rotating the suction nozzle, the step of placing the calibration gauge, and the step of taking the second ~~mage,~~ image, and the step of processing the first and second images may comprise processing the first image and at least two second images to determine the relative position between the reference point of the calibration member and the position of the rotation axis of the suction nozzle. According to this feature, the position of the rotation axis of the suction nozzle can be detected on the plane including the component-mounting surface of the circuit substrate. In addition, an error of a relative position between the rotation axis of the nozzle and the image-taking device can be detected while the first positioning reference of the calibration member is used as a parameter. According to this feature, it is preferred to use, as the image-taking device, a fiducial-mark- image taking device employed for taking an image of at least one fiducial mark provided on the circuit substrate. In the latter case, an error of a relative position between the rotation axis of the suction nozzle and the fiducial-mark-image taking device can be detected easily and accurately.

Please replace paragraph **[0013]** with the following rewritten paragraph:

[0013] (4) A method of detecting a position of a rotation axis of a suction nozzle of an electric-component mounting apparatus, the suction nozzle holding, by suction, an electric component, the mounting apparatus including a fiducial-mark-image taking device that takes an image of at least one fiducial mark provided on a circuit substrate, determining, based on the taken image, a position of the circuit substrate, moving, according to the determined

position, the suction nozzle holding the electric component, toward the circuit substrate, and rotating the suction nozzle about the rotation axis thereof to rotate the electric component to a predetermined angular position, so that the electric component taking the predetermined angular position is mounted at a predetermined position on a component- mounting surface of the circuit substrate, the method comprising the steps of:

preparing a calibration member having a support surface parallel to the component-mounting surface, and having at least one first positioning reference,

placing, on the support surface, a calibration gauge having at least one second positioning reference,

taking, with the fiducial-mark-image taking device, a first image of the first positioning ~~image~~ reference and the second positioning ~~image,~~ reference,

holding, with the suction nozzle, the calibration gauge to move the gauge off the support surface,

rotating the suction nozzle holding the calibration gauge, about the rotation axis of the nozzle, to rotate the gauge by a predetermined angle,

placing, with the suction nozzle, the calibration gauge rotated by the predetermined angle, on the support surface,

taking, with the fiducial-mark-image taking device, a second image of the first positioning ~~image~~ reference and the second positioning ~~image,~~ reference and

processing the first image and the second image, to determine a relative position between a reference point of the calibration member and the position of the rotation axis of the suction nozzle.

Please replace paragraph **[0014]** with the following rewritten paragraph:

[0014] The present method may further comprises repeating, at least one more time, the step of holding the calibration gauge, the step of rotating the suction nozzle, the step of

placing the calibration gauge, and the step of taking the second ~~mage,~~ image, and the step of processing the first and second images may comprise processing the first image and at least two second images to determine the relative position between the reference point of the calibration member and the position of the rotation axis of the suction nozzle. According to this invention, an error of a relative position between the fiducial-mark-image taking device and the rotation axis of the suction nozzle can be detected easily and accurately. It is noted that according to this invention, it is not essentially required that the support surface of the calibration member should be provided on the plane including the component-mounting surface of the circuit substrate.

Please replace paragraph **[0022]** with the following rewritten paragraph:

[0022] Since the calibration ~~gauge~~ member has the reference marks on the upper surface thereof level with an upper surface of the calibration gauge, a sharp or clear image of the respective reference marks of the calibration member and the calibration gauge can be taken at one time and accordingly the accuracy of detection of positions can be easily improved.

Please replace paragraph **[0037]** with the following rewritten paragraph:

[0037] The above and other objects, features, advantages and technical and industrial significance of the present invention will be better understood by reading the following detailed description of preferred embodiments of the invention, when considered in connection with the accompanying drawings, in which:

Fig. 1 is a plan view showing an electronic- component mounting system constructed according to one embodiment of this invention;

Fig. 2 is a side elevational view of the electronic-component mounting system of Fig. 1;

Fig. 3 is a front elevational view showing a component mounting device in the electronic-component mounting system;

Fig. 4 is a side elevational view, partly in cross section, of the component mounting device of Fig. 3;

Fig. 5 is a side elevational view schematically showing a printed-wiring board support device of the electronic-component mounting system;

Fig. 6 is a side elevational view showing an electronic component accommodated in a component tray in the electronic-component mounting system;

Fig. 7 is a side elevational view, partly in cross section, showing a component mounting unit of the component mounting device of Fig. 3;

Fig. 8 is a side elevational view, in cross section, showing a component holding device of the component mounting unit of Fig. 7;

Fig. 9 is a perspective view of a calibration platform for the component mounting unit, and an attaching device for attaching the calibration platform;

Fig. 10 is an exploded, perspective view of the calibration platform of Fig. 9;

Fig. 11 is a perspective view for explaining a manner in which a height position of the calibration platform is adjusted;

Fig. 12 is a plan view of the calibration platform;

Fig. 13 is a ~~lock~~ block diagram schematically illustrating a control device of the electronic-component mounting system;

Fig. 14 is a flow chart representing a control program that is stored in a RAM (random access memory) of the control device of Fig. 13;

Fig. 15 is a flow chart representing another control program that is stored in the RAM of the control device;

Fig. 16 is an illustrative view for explaining an operation of the electronic-component mounting system;

Fig. 17 is a view for explaining a technical advantage of the electronic-component mounting system;

Fig. 18 is a plan view showing an electronic- component mounting system according to another embodiment of this invention; and

Fig. 19 is a plan view showing an electronic- component mounting system according to yet another embodiment of this invention.

Please replace paragraph **[0041]** with the following rewritten paragraph:

[0041] Each of the two guide rails 30, 32 is constructed to guide an endless conveyor belt 34 such that the belt 34 can travel in a ~~hoop.~~ loop. The printed-wiring board 12 is placed on the conveyor belts 34, and is transferred by the conveyor belts 34 when the conveyor belts 34 are rotated in synchronization with each other by a drive source in the form of a printed-wiring board feed motor (PWB feed motor) 36 indicated in the block diagram of Fig. 13. As schematically shown in Fig. 5, the printed-wiring board support device 26 includes a pair of clamping members 40 and a plurality of supporting members 42. Each of the clamping members 40 takes the form of a plate fixed upright at a corresponding one of opposite ends of an elevator platform 44 such that the two clamping members 40 extend in the X-axis direction, namely, in the direction of movement of the board 12. The plurality of supporting ~~member~~ members 42 are fixed upright in a widthwise intermediate portion of the elevator platform 44 which is located intermediate between the two clamping members 40. The elevator platform 44 is located under the printed-wiring board 12 at the predetermined component-mounting position, such that the elevator platform 44 is opposed to the lower surface of the board 12 which is opposite to the component-mounting surface 28 on which the electronic components are mounted by the present electronic-component mounting system.

The elevator platform 44 is lifted and lowered by an elevator drive device 50, which includes a drive source in the form of a fluid-operated actuator such as a fluid-operated cylinder. In the specific example of Fig. 5, the elevator drive device 50 uses, as the drive source, an elevator cylinder 52 which is a pneumatic cylinder. The elevator cylinder 52 is disposed so as to extend in the vertical direction, and includes a piston rod 54 for engagement with the elevator platform 44.

Please replace paragraph **[0045]** with the following rewritten paragraph:

[0045] Thus, the component mounting device 18 receives the electronic components one after another from the component tray 76 in the tray ~~boxy~~ box 78 at the component-supply position above which the required vertical space is provided. Each component tray 76 accommodates the electronic components 82 in component accommodating recesses 80 (Fig. 6) which are arranged in a matrix. Each electronic component 82 accommodated in the corresponding recess 80 is substantially positioned, so that the electronic component 82 can be held at an almost central portion thereof by the component mounting device 18, and can be taken out of the recess 80, while the electronic component almost maintains predetermined attitude and position relative to the component mounting device 18. In the specific example of Fig. 6, the electronic component 82 has a multiplicity of leads 92 extending from the four side faces of a rectangular body 90. The electronic component 82 is mounted at its bottom surface 96 on the printed-wiring board 12 so that the leads 92 are connected to the printed wiring of the board 12. The electronic component 82 has a top surface 94 opposite to the bottom surface 96. The electronic component 82 may be provided with a ball-grid array, or may not have the leads 92.

Please replace paragraph **[0054]** with the following rewritten paragraph:

[0054] A light emitting plate 206 is fixedly mounted on the outer circumferential surface of the lower end portion of the sleeve 190 which is located outside the chuck 182,

while the suction ~~nozzle~~ pipe 192 is partially fitted in the inner circumferential surface of the lower end portion of the sleeve 190, such that the suction ~~nozzle~~ pipe 192 extends downwards through the light emitting plate 206. When the position of the electronic component 82 held by the suction nozzle 184 is detected, the light emitting plate 206 receives an ultraviolet radiation, and generates a visible light toward the electronic component 82.

Please replace paragraph **[0063]** with the following rewritten paragraph:

[0063] A strobe light 260 as a ~~UL~~ UV irradiating device is disposed near the reflecting mirror 252, for irradiating the light emitting plate 206 of the suction nozzle 184 with an ultraviolet radiation. The light emitting plate 206 absorbs the ultraviolet radiation, and emits a visible light for illuminating the top surface 94 of the electronic component 82 held by the suction nozzle 184. The component camera 250 takes a silhouette image of the electronic component 82 in the axial direction of the suction nozzle 184, with the light emitting plate 206 used as a light background. In the present embodiment, the light emitting plate 206 and the strobe light 260 provided as the UV irradiating device cooperate to constitute an illuminating device for the image-taking device 248. Another strobe light 262 for emitting a visible light is disposed nearer to the suction nozzle 184 than the above-indicated strobe light 260. This strobe light 262 serves as an illuminating device for illuminating the ball-grid array at a relatively small angle with respect to the bottom surface 96 of the electronic component 82. The strobe light 260 may be used as an illuminating device for irradiating the bottom surface 96 of the electronic component 82 with a visible light, for taking a normal image of the electronic component 82 rather than a silhouette image. If necessary, the image-taking device 248 may use two illuminating devices which are selectively used for taking the silhouette image and the normal image of the electronic component 82, respectively.

Please replace paragraph **[0065]** with the following rewritten paragraph:

[0065] The ballscrews 104 are supported by the machine base 10 such that one end portion of each of the ballscrews 104 that is rotated by a corresponding one of the X-axis drive motors 110 is rotatable, and is not movable in an axial direction of the each screw 104 and the other end portion of the each screw 104 is rotatable and movable in the axial direction; and the ~~ballsrew~~ ballscrew 120 is supported by the X-axis slide 106 such that one end portion of the ballscrew 120 that is rotated by the Y-axis drive motor 126 is rotatable, and is not movable in an axial direction of the screw 120 and the other end portion of the screw 120 is rotatable and movable in the axial direction. Accordingly, the amounts of thermal deformation and elastic deformation of the ballscrews 104, 120 are smaller at their end portions near to the first calibration platform 266, than those at their end portions near to the second calibration platform 268. The first calibration platform 266 is desirably located at a position at which the thermal deformation and elastic deformation of the ballscrews 104, 120 are negligibly small. However, the two calibration platforms 266, 268 may be located near respective diagonally opposite corners of the rectangular printed-wiring board 12 supported by the printed-wiring board support device 26. In this case, the two diagonally opposite corners of the board 12 correspond to the above-indicated two corners of the rectangular region of movement of the component holding device 100.

Please replace paragraph **[0067]** with the following rewritten paragraph:

[0067] The four reference surfaces 286 have respective reference marks 288. Each of the reference marks 288 has an optical characteristic different from that of each of the reference surfaces 286. Preferably, each reference surface 286 is one of white and black and each reference mark 288 is the other of white and black. Each reference mark 288 may have any shape but preferably has such a shape that assures that the mark 288 is easily detectable to determine a position thereof. In the example shown in Fig. 11, each reference mark 288 has a

circular shape. However, each reference surface 286 may have a hole as a reference mark. As shown in Fig. 12, a calibration gauge 290 is placed on the upper surface of the calibration platform 266. To this end, the calibration platform 266 has a recessed support surface 292 which can support, with more or less allowance, the calibration gauge 290. A depth of the recessed support surface 292 is determined to be equal to a thickness of the calibration gauge 290, and accordingly, in the state in which the surface 292 supports the gauge 290, an upper surface of the gauge 290 is level with the reference surfaces 286. The calibration platform 266 has a suction hole 294 which is formed through a central portion of the support surface 292 and is connected to a negative- pressure supply device 296 (Fig. 13) via a joint 295. The suction hole 294 is provided with a filter 297.

Please replace paragraph **[0072]** with the following rewritten paragraph:

[0072] The bus 308 is also connected to a digital input interface 318 and a digital output interface 320. To the digital input interface 318, there are connected the encoders 170, 176 described above, and other encoders such as those for detecting the amounts of operation of the X-axis drive motors 110. To the digital output interface 320, there are connected the printed- wiring board feed motor (PWB feed motor) 36, a control valve for the elevator cylinder 52, the negative-pressure supply device ~~192,~~ 296, and other actuators. The RAM 306 stores various control programs such as those for executing a main control routine, not shown, a first automatic-calibration control routine shown in Fig. 14, a second automatic-calibration control routine shown in Fig. 15, and an electronic-component-mounting control routine. The control device ~~360~~ 300 also controls the image taking operations of the fiducial mark camera 240 and the image-taking devices 248, although not illustrated in Fig. 13.

Please replace paragraph **[0077]** with the following rewritten paragraph:

[0077] At Step S10, the suction nozzle 184 ~~hold,~~ holds, by suction, the calibration gauge 290 and moves the gauge ~~190~~ 290 off the first calibration platform 266 and, at Step S11, the nozzle 184 places the gauge 290 on the second calibration platform 268. At Step S12, an image of the gauge 290 is taken by the fiducial mark camera 240, and the image processing device 312 determines, based on the taken image, positional errors ΔX3, ΔY3 of the center point of the calibration gauge 290 from the center point of the imaging area of the fiducial mark camera 240, and stores the thus determined positional errors in the RAM 306.

Please replace paragraph **[0078]** with the following rewritten paragraph:

[0078] At Step S13, the image processing device 312 calculates first differences, ΔX1 - ΔX2, ΔY1 - ΔY2, as differences between the positional errors associated with the placing of an object on the standard substrate 324 and the positional errors associated with the placing of the object on the first calibration platform 266, and calculates second differences, ΔX1 - ΔX3, ΔY1 - ΔY3, as differences between the positional errors associated with the placing of the object on the standard substrate 324 and the positional errors associated with the placing of the object on the second calibration platform ~~266.~~ 268. The thus determined first differences ΔX1 - ΔX2, ΔY1 - ΔY2 and second differences ΔX1 - ΔX3, ΔY1 - ΔY3 are stored in respective predetermined memory areas of the RAM 306. Those differences are part of the characteristic values of the present electronic-component mounting system, and will be used as part of correction values to correct a predetermined component-mounting position or place when each electronic component 82 is mounted at the predetermined component-mounting place on the printed-wiring board 12.

Please replace paragraph **[0079]** with the following rewritten paragraph:

[0079] Next, the second automatic-calibration control routine of Fig. 15 will be described. At Step S21 starting with a state in which the calibration gauge 290 is placed on the first calibration ~~gauge~~ platform 266, the suction nozzle 184 is moved to the predetermined coordinate point (G, H) representing the center point of the calibration platform 266, i.e., the nominal position of the platform 266, and holds, by suction, the gauge 290. At Step S22, the suction nozzle 184 holding the gauge 290 is moved to the nominal position of the image taking device 248, and an image of the gauge 290 is taken. The image processing device 312 determines, based on the taken image, positional errors ΔX4, ΔY4 of the center point of the gauge 290 from the center point of the imaging area of the component camera 250, and stores the thus determined positional errors in the RAM 306. The center point of the gauge 290 is determined as an average of respective coordinate points representing, in a coordinate system whose origin rides on the center point of the imaging area of the camera ~~240,~~ 250, respective center points of the four reference holes 298 formed in the four corners of the gauge 290. At Step S23, the suction nozzle 184 is moved to the nominal position of the first calibration platform 266, and places the calibration gauge 290 on the calibration platform 266. At Step S24, the fiducial mark camera 240 takes an image of the calibration gauge 290 and the calibration platform 266, and the image processing device 312 determines, based on the taken image, a relative position ΔX5, ΔY5 of the center point of the platform 266 relative to the center point of the imaging area of the fiducial mark camera 240, and a relative position ΔX6, ΔY6 of the center point of the gauge 290 relative to the center point of the imaging area of the camera 240, and stores the thus determined relative position ΔX5, ΔY5 and relative position ΔX6, ΔY6 in respective predetermined memory areas of the RAM 306. The center point of the platform 266 is determined as an average of respective coordinate points representing respective center points of the four reference marks 288 of the platform 266. The center point

of the gauge 290 is determined as an average of respective coordinate points representing the respective center points of the four reference holes 298 of the gauge 290. Next, at Step S25, a number, n, counted by a counter is incremented by one and, at Step S26, the suction nozzle 184 is moved to the nominal position of the first calibration platform 266 to hold, by suction, the calibration gauge 290 and move the gauge 290 off the platform 266. At Step S27, the suction nozzle 184 holding the gauge 290 is rotated by a predetermined angle (e.g., 90 degrees) and, at Step S28, the nozzle 184 is moved again to the nominal position of the platform 266 to place the gauge 290 on the platform 266. At Step S29, the fiducial mark camera 240 is moved to the nominal position of the platform 266 to take an image of the gauge 290 and the platform 266, and the image processing device 312 determines, based on the taken image, relative coordinate points representing respective positions of the respective center points of the platform 266 and the gauge 290, and stores the thus determined coordinate points in the RAM 306. At Step S30, the control device 300 judges whether the number n counted by the counter is equal to, or greater than, three. Steps S25 to S29 are repeated till a positive judgment is made at Step S30. Thus, the control device 300 obtains four coordinate points representing the center point of the platform 266, and four coordinate points representing the center point of the gauge 290, when the suction nozzle 184 takes the four angular positions, e.g., 0 degree, 90 degrees, 180 degrees, 270 degrees, respectively. If a positive judgment is made at Step S30, the control goes to Step S31 to determine an average of the four coordinate points obtained for the gauge 290, as a coordinate point representing a position of the rotation axis of the nozzle 184, determine an average of the four coordinate points obtained for the platform 266, as a coordinate point representing a position of the center point of the platform 266, and determine a positional error of the rotation axis of the nozzle 184 from the center point of the platform 266. In addition, the thus determined coordinate point representing the position of the center point of the platform 266, and

determined positional error of the rotation axis of the nozzle 184 are stored in respective memory areas of the RAM 306.

Please replace paragraph **[0087]** with the following rewritten paragraph:

[0087] The principle of the present invention is also applicable to an electronic-component mounting system of a type shown in Fig. 19, which includes a multiplicity of component holders 360 which have respective suction nozzles 184 and which are fixedly disposed on one index table 362. The component holders 360 are turned about the axis of rotation of the index table 362 when the index table 362 is intermittently rotated at a predetermined angular interval. The present system further includes an angular positioning device 364 for ~~rotating~~ rotating, and positioning, the index table 362 ~~at~~ to, and at, a plurality of predetermined working stations which are arranged on a circular path of movement of the component holders 360, so that the suction nozzle 184 held by each component holder 360 can be turned about a turning axis (i.e., an axis of the index table 362) and stopped at the working stations. The system further includes a PWB support device 366 for supporting the printed-wiring board 12, and an XY positioning device 370 for positioning the PWB support device 366 in the X-axis and Y-axis directions in the XY plane parallel to the upper surface 28 of the printed-wiring board 12. The XY positioning device 370 includes an X-axis slide 376 movable by an X-axis drive motor 372 and a ballscrew 374, and a Y-axis slide which is movable on the X-axis slide 376 by a Y-axis drive motor 378 and a ballscrew 380. The PWB support device 366 is mounted on the Y-axis slide. An image-taking device 384 which includes a component camera and a waveguide device and which is operable to take an image of the electronic component 82 is fixedly disposed at a position at which the component camera is opposed to the end face of the suction nozzle 184 of the component holder 360 located at one of the above-indicated working stations. A first rotating device (not shown) is fixedly disposed above the image-taking device ~~380~~ 384 and the corresponding component

holder 360, for rotating this component holder 360. A second rotating device (not shown) is fixedly disposed at the working station between the working station at which the image-taking device 384 is disposed, and the working station at which the electronic component 82 is mounted on the printed-wiring board 12. The second rotating device is provided to rotate the component holder 360 to eliminate an angular-positional error of the electronic component 82. A Z-axis drive device (not shown) is provided to lift and lower the suction nozzle 184 for holding the electronic component 82 and for mounting the electronic component 82 on the board 12. A fiducial mark camera 386 is fixedly disposed for taking an image of each of fiducial marks provided on the printed-wiring board 12 supported on the PWB support device 366. In the interest of simplicity, Fig. 19 does not show support structures for supporting the index table 362, image-taking device 384, fiducial mark camera 386, and a dog 390. The index table 362 may be replaced by a plurality of rotary members which are rotated about a common axis of rotation by a cam device, at a controlled rotating velocity, so that the rotary members are stopped at a plurality of working stations at different times. For instance, the rotary members hold respective component holders 360 such that the component holder 360 held by each rotary member is rotatable and axially movable relative to the rotary member. If the present electronic- component mounting system of Fig. 19 employs the above- described calibration platforms 266, 268 and calibration gauge 290, the system can enjoys the same advantages as those of the system shown in Figs. 1 and 2.